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54 Process for measuring cutting edges

The cutting edges (2) at the circumference of a rotating milling tool (1) and the optical sensing device (7) are moved in relation to each other. The positions of this progressive movement are recorded by a path measuring system (6). The coherent beam produced by the light source (8) of the optical sensing device (7) is focused on the measuring plane (12). The positions of the path measuring system (6) on interuptions in the beam by the cutting edges (2) are recorded in an analytical device (15).

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DESCRIPTION

The invention concerns a process for the contactless measuring of cutting edges at the circumference of a turning milling tool whereby the cutting edges are captured by the beam from a sensing device consisting of a light source and a photo detector in the measurement plane containing the axis of the cutting tool, the optical axis of which runs horizontal to the measuring plane and tangentially to the flight of the cutting edges.

The cutting edges of milling tools are measured to ascertain the rotatory error and diameter of the flight. The rotatory error of the cutting edges on milling tools is an important parameter both for the accuracy of production and for the profitability of the milling process. The consequences of an unacceptably high rotatory error are, amongst other things, reduced tool life as a result of vibration and differences in cutting load, increased loading of the machine, especially its main spindle, distorted measurements and reduced surface quality of the workpiece.

Static circulatory error in the cutting edges already arises when the milling tool is turning slowly or standing still and is caused by a misalignment of the cutting edges to the tool as a result of adjustment errors in adjustable tools or through production tolerances for monolithic workpieces and tools with welded blades.

Dynamic rotatory error in the cutting edges occurs only at higher speeds of the milling tool and are due to bending of the tool as a result of imbalances and the ensuing out-of-balance forces, generally due to the rotary frequency. Centrifugal forces in the area of the tool clamps can for example result in rotatory errors depending on the rotatory frequency through a widening of the collet chucks. Other causes of static or dynamic rotatory error may be clamping errors through tolerances in the tool mounting and possibly in the tool chuck or pollution in these areas. These causes of error are of particular importance since the clamping error arising can change after each successive workpiece. This is a serious problem for final processing on unattended machine tools. Rotatory error in the milling spindles can also take the form of dynamic rotatory error in the milling tool.

The dynamic rotatory error dependent on the rotatory frequency of the milling spindles is of particular importance for fast running spindles, especially during high speed cutting, because the centrifugal forces arising increase by the square of the frequency of rotation. For rotatory error of significance to the output of the work to be fully registered, it is therefore necessary for milling tools to be measured in clamped state and at the operating rotatory frequency.

Known processes for contactless measuring of cutting edges at the circumference of the milling tool working with a laser scanner are, because of their operating method, unsuitable for use on rotating milling tools. Under this process the projection of the cutting edges is measured; however, this alters continuously during rotation. This laser scanning process cannot therefore be used for measuring milling tools while they are rotating, especially not at high rotatory frequencies.

Under a known procedure of the type mentioned above (Stöferle and Hartmann, Beitrag zur Lagemessung aller Schneidkanten an Fräswerkzeugen, Z. Werkstatt und Betrieb 109 (1976) 3, pp. 183 and 188, picture 12) an image of the cutting edge located in the measuring plane is created on a photo detector which takes the form of a photo diode line. Depending on the number of photo diodes exposed, the radius of the flight of the cutting edge is ascertained. During the measurement process, the mutual distance between the milling axis and the optical axis of the optical scanning device remains constant. It is particularly important for accuracy of measurement that the cutting edge lies as precisely as possible in the measuring plane at the time of the measuring process. This essentially already difficult requirement becomes yet more difficult with a substantially greater frequency of milling rotation and can no longer be maintained at the rotatory frequencies customary with modern high-speed milling processes. The known process cannot therefore be used for measuring fast-running milling devices, especially for high speed milling.

The purpose of the invention is therefore to devise a process of the kind mentioned above that can be used for fast-running milling tools, especially at the operating rotatory frequencies customary in high speed milling.

This task is solved in accordance with the invention by a coherent beam of light created from a light source being focused on the measuring plane and the light source being formed on the active surface of the photo detector, the milling device and the optical sensing device being moved relative to each other during the measuring process in the common standard direction of the milling axis and the optical axis, the relative movement being recorded by a path measuring system, and the position of the path measuring system being measured in one evaluation direction while the beam from the optical sensing device is interrupted.

Unlike in the known processes, the cutting edge is not portrayed on the active surface of the photo detector; rather, the light beam is focused in the measurement plane, i.e. the light source is formed on the active surface of the photo detector. Because of the focusing in the measurement plane, the optical sensing device in accordance with the invention is capable of forming an optical sensor of very small dimensions. This optical sensor, formed by a focused light beam, is used only to ascertain whether a cutting edge is located within the measuring point or not. As soon as a cutting edge interrupts the beam focused in the measuring plane, the total active surface of the photo detector is essentially darkened.

As a result of the relative progressive movement provided under the invention between the optical sensing device and the milling device to be measured, the measuring process proceeds by a path measuring system recording the position of this progressive movement at particular points in time. The accuracy of measurement is therefore determined only by the accuracy of this path measurement system which can be set extremely high and does not depend on the rotatory frequency of the milling tool. The dynamic rotatory error occurring during operational rotatory frequencies on high speed milling can therefore also be recorded.

In accordance with a preferred embodiment of the process according to the invention, the rotatory frequency of the milling tool is recorded by a rotatory frequency transmitter, and a rotatory frequency signal is transferred to the analytical device and the analytical device ascertains the number of interruptions in the beam from the optical sensing device for each revolution of the milling tool. This simultaneous recording of the rotatory frequency of the

milling tool and the linkage to the number of interruptions in the beam allows not only the cutting edge projecting farthest radially in each case but also the other cutting edges to be measured.

As an onward development of this inventive idea, as the optical sensing device approaches the milling tool, the positions of the path measuring system are recorded on the initial occurrence of an interruption in the beam and at the time when the number of interruptions per revolution of the milling tool is equal to the number of blades on the tool, and the distance between these two positions is ascertained in the analytical device as a measure of the rotatory error of the milling tool.

In accordance with another advantageous development of the inventive idea, the optical sensing device and the milling tool are moved in relation to each other across the diameter of the latter, the positions of the path measuring system being thereby recorded on the initial and last occurrence of an interruption in the beam, and the analytical device ascertaining the distance between these two positions as a measurement of the flight diameter of the milling tool.

The embodiments of the invention are further explained below by means of the drawing. Here:

Fig. 1 is a highly simplified presentation of a facility for the contactless measuring of cutting edges on the circumference of a rotating milling tool and

Fig. 2 is a simplified top view of signal processing in the device according to **Fig. 1**.

A milling tool 1 has at its circumference a number of cutting edges 2 to be measured. The milling tool 1 is mounted on a milling spindle 3, which is bedded in a carriage 4 and driven at its operational rotating frequency. The carriage 4 be moved in a progressive direction indicated by an arrow 5. This progressive movement is recorded by a path measuring system 6.

An optical sensing device 7, which is composed in the fashion of a light barrier consists of a light source 8, which transmit coherent light. The beam 9 emitted by the light source 8 impinges in parallel to an optical axis 10 on a focusing lens 11 and is focused by the latter onto a measuring plane 12, creating an image of the light source 8 on the active surface of a photo detector 13.

The progressive movement of the milling tool 1 proceeds along the measuring plane 12 in which the milling axis 14 of the milling tool 1 also lies. The milling tool 1 is moved in the common standard direction of the milling device axis 14 and the optical axis 10.

In the embodiment shown in Fig. 1, the relative movement of the milling tool 1 to the optical sensing device 7 is due to the shifting of the carriage 4 in which the milling tool 1 is bedded. The drive mechanism for the carriage 4 in any event present and its path measuring system are used for this purpose.

It is also possible, instead, to move the sensing facility 7 in relation to the milling tool 14 by a separate shifting device and a path measurement system.

A rotatory frequency transmitter 15 connected to the milling spindle 3 supplies a rotatory frequency signal to an analytical device 16 to which the output signals from the photo detector 13 are also conveyed. The path signals for the path measurement system 16 are also supplied to the analytical device 16.

Details of signal processing appear in Fig. 2.

The output signals from the photo detector 13 produced by the optical sensing device 7, shown only diagramatically in Fig. 2, are amplified in a measurement transformer 17 and converted to a binary signal 18 by a compactor circuit. The status of this binary signal 18 (0 or 1) indicates whether the light beam in the optical sensing device 7 has been interrupted in the measuring plane 12 by a cutting edge 2, or not.

The rotatory frequency transmitter 19 creates a binary signal 21 through a measuring transformer 20 with a frequency equal to the frequency of rotation of the milling tool 1 to be measured.

A pulse counter 22, to which the binary signal 18 is supplied, is a binary counter with an 8 bit digit system. The pulse counter 22 works circumferenciality, i.e. it transfers to value 0 to the next pulse of signal 21 after the highest counter position of 25 has been reached.

A break recorder 23 is used to scan the counter position of the pulse counter 22 synchronously with the rotatory frequency of the milling tool 1. The counter position of the pulse counter 22 is transferred with the (arbitrarily fixed) active flank of the signal 21 to the break recorder 23 where it is kept up to the next active flank of the signal 21.

A micro-computer 24, to which the signals 18 and 21 and the output signal from the break recorder 23 are transferred, takes the form of a traditional micro-processor system, comprising a micro-processor, a read-only memory (ROM) for program storage, a write-read memory (RAM) serving as a working store, a programmable parallel interface component (VIA) and several auxiliary circuits such as pulse generator, power driver, and the like.

An output to the micro-computer 24 is connected to the display unit 25 which serves to display the status of the signal 18, to indicate the ascertained number of cutting edges 2 impinging on the light beam, and to signal the system statuses (readiness and error messages).

The rotatory error at the cutting edges 2 of the milling tool 1 is measured as follows. On the movement of the carriage 4, the milling tool 1 to be measured, together with its operating rotatory frequency, and the optical sensing device 7 are positioned towards each other in such a way that the beam emitted by the light source 8 reaches the photo-detector 13 and is not interrupted by a cutting edge 2 of the milling tool 1. This is detected by the downstream analysis unit 16 and displayed.

The milling tool 1 and the optical scanning device 7 are moved in relation to each other by the shifting device for the carriage 4 until at least one cutting edge 2 has impinged on the beam and interrupts it periodically (through the rotation of the milling tool 1). This leads to a periodic change in the output signal 18 of the photo detector 13. The counter position of the pulse counter 22 is transferred synchronously to the rotatory frequency of the milling tool 1

through the break recorder 23 to the micro-computer 24 in the connected processing device 16. The micro-computer 24 calculates the difference in each case to the previous counter position and consequently the number of interruptions in the beam for each revolution of the tool. The value ascertained is displayed on the display device 25. The path measuring system 6 produces a first position in the state where the beam in measuring plane 12 is interrupted for the first time by a cutting edge 2 during the progressive movement.

A further progressive movement then occurs until the displayed number of interruptions in the beam for each revolution of the milling tool is equal to the number of cutting edges 2 on the milling tool 1. This second position is similarly recorded by the path measurement system 6. The path difference in these two positions of the path measuring system 6 is calculated by the sensing device 16: this path difference corresponds to the difference between the largest and smallest distance between the cutting edges 2 and the spindle axis 14 and so constitutes the rotatory error in the milling tool 1.

To measure the flight diameter of the milling tool 1, the position in which the cutting edge 2 first interrupts the beam from the optical sensing device 7 in the way already described in the path measurement system 6. The carriage 4 is then shifted in its progressive direction 5 until the beam from the optical sensing device 7 is no longer interrupted. The position of the path measuring system 6 is recorded when the beam last occurs. The difference in the path of these two positions is calculated in the analytical device 16; it corresponds to the flight diameter of the milling tool 1.

The detection of the frequency of rotation of the milling device 1 by the separate rotatory frequency transmitter 15 can be dispensed with if the rotatory frequency of the milling device 1 is precisely recorded during measurement by the machine tool control and/or if a signal corresponding to the signal 21 is available at another position in the control, but can be used in the same way.

In describing the embodiment shown, it was assumed that the optical axis 10 of the optical sensing device 7 follows the rotary milling axis 3 and the measurement axes connecting them in which the progressive movement 5 takes place are at right angles to each other. Departures from this rectangular arrangement will produce a systematic measurement error; however, this can be arithmetically corrected so that operations of this kind can be accepted. However, it is important that the optical access 10 of the optical sensing device 7 cuts the measuring plane 12 formed by the rotatory milling axis 3 and the positional axis determined by the progressive movement 5 at the focus of the beam.

Patent Claims

1. Process for the contactless measuring of cutting edges at the circumference of a rotating milling tool, where the cutting edges are recorded in each case in the measurement plane contained in the milling tool axis by a beam from an optical sensing device consisting of a light source and a photo detector, the optical axis of which proceeds at right angles to the measurement plane and tangentially to the flight of the cutting edges, **characterised in that** a coherent light beam created by the light source (8) focuses in the measurement plane (12) and the light source (8) is formed on the active surface of the photo detector (13), that the milling tool (1) and the optical sensing device (7) are moved in relation to each other during the measuring process, that this relative movement is recorded by a path measuring system (6),

and that the position of the path measuring system (6) is recorded in an analytical device (10) when the beam from the optical sensing device (7) is interrupted.

2. Process as claimed in claim 1, characterised that the relative movement of the milling tool (1) and the optical sensing device (7) proceeds in the common standard direction of the milling tool axis (14) and the optical axis (10).

3. Process as claimed in claim 1, characterised in that the rotating frequency of milling tool (1) is recorded by a rotatory frequency transmitter (15) and a rotatory frequency signal is conveyed to the analytical device (16) and that the number of interruptions in the beam from the optical sensing device is recorded for each revolution of the milling tool (1) in the analytic device (16).

4. Process as claimed in claims 1 and 3 characterised in that as the optical sensory device (7) approaches the milling tool (1) the positions of the path measuring system (6) are recorded when an interruption first occurs in the beam and at the time when the number of interruptions for each revolution of the milling tool (1) is equal to the cutting number of the milling tool and that the distance between these two positions is recorded in the analytical device (16) as a measurement of the rotatory error of the milling tool (1).

4. Process as claimed in claim 1, characterised in that the optical sensing device (7) and milling tool (1) are moved in relation to each other through its diameter, that the positions of the path measuring system (6) are thereupon recorded on the first and last occurrence of an interruption in the beam, and that the distance between these two positions is recorded in the analytical device (16) as a measurement of the flight diameter of the milling tool (1).

Two pages of drawings in this connection
